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ORISE

OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

August 1, 2001

Robert Atkin
U.S. Department of Energy
Oak Ridge Operations Office
P.O. Box 2001
Oak Ridge, TN 37831

SUBJECT: CONTRACT NO. DE-AC05-00OR22750
FINAL REPORT—VERIFICATION SURVEY OF THE NEW BRUNSWICK LABORATORY SITE, NEW BRUNSWICK, NEW JERSEY

Dear Mr. Atkin:

The Environmental Survey and Site Assessment Program (ESSAP) of the Oak Ridge Institute for Science and Education (ORISE) conducted verification surveys at the New Brunswick Laboratory Site, located in the town of New Brunswick, New Jersey, during the period of August through November 1996. A draft report detailing the procedures and results of the survey was submitted to the U.S. Department of Energy (DOE) on June 3, 1997. After the submittal of the draft report, the Formerly Utilized Sites Remedial Action Program (FUSRAP), was transferred to the U.S. Army Corps of Engineers (ACE) from the DOE. The ACE did not retain the independent verification contract with ORISE and a final report was not requested until July 2001, when DOE contacted ORISE and stated that the DOE had no comments on the draft report.

Enclosed are three copies of the subject report. If you have any questions, please direct them to me at (865) 576-3355 or Tim Vitkus at (865) 576-5073.

Sincerely,

Duane R. Quayle
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VERIFICATION SURVEY OF THE NEW BRUNSWICK LABORATORY SITE NEW BRUNSWICK, NEW JERSEY

D. R. QUAYLE and T. D. HERRERA

Prepared for the
Office of Environmental Restoration
U.S. Department of Energy

ORISE
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
Environmental Survey and Site Assessment Program

The Oak Ridge Institute for Science and Education (ORISE) was established by the U.S. Department of Energy to undertake national and international programs in education, training, health, and the environment. ORISE and its programs are operated by Oak Ridge Associated Universities (ORAU) through a contract with the U.S. Department of Energy. Established in 1946, ORAU is a multiuniversity consortium.

VERIFICATION SURVEY OF THE NEW BRUNSWICK LABORATORY SITE NEW BRUNSWICK, NEW JERSEY

Prepared by

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Office of Environmental Restoration
U.S. Department of Energy

FINAL REPORT

JULY 2001

This report was based on work performed under contract number DE-AC05-00OR22750 with the U.S. Department of Energy.

VERIFICATION SURVEY
OF THE
NEW BRUNSWICK LABORATORY
NEW BRUNSWICK, NEW JERSEY

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ABBREVIATIONS AND ACRONYMS

µR/h	microroentgens per hour
AEC	Atomic Energy Commission
BKG	background
BNI	Bechtel National, Inc.
cm	centimeter
cpm	counts per minute
DOE	U.S. Department of Energy
DOE-HQ	DOE-Headquarters
DOE-ORO	DOE-Oak Ridge Operations
dpm/100 cm^2	disintegrations per minute per 100 square centimeters
EML	Environmental Measurements Laboratories
EPA	Environmental Protection Agency
ESSAP	Environmental Survey and Site Assessment Program
FSRD	Former Sites Restoration Division
FUSRAP	Formerly Utilized Sites Remedial Action Program
GM	Geiger Muller
IVC	Independent Verification Contractor
kg	kilogram
km	kilometer
m	meter
m^3	cubic meters
MDC	minimum detectable concentration
MeV	million electron volts
mrem/yr	millirem per year
mrad/h	millirad per hour
NaI	sodium iodide
NBL	New Brunswick Laboratory
NIST	National Institute of Standards and Technology
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
pCi/g	picocuries per gram
PMC	Project Management Contractor
post-RA	post-remedial action
PRAR	post-remedial action report
SGS	segmented gate system
ZnS	zinc sulfide

VERIFICATION SURVEY
OF THE
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NEW BRUNSWICK, NEW JERSEY

INTRODUCTION

The property formerly containing the structures collectively known as the New Brunswick Laboratory (NBL), is located in the town of New Brunswick, New Jersey. A manufacturing company contracted by the U.S. Navy to build pumps developed the site during World War II. The Atomic Energy Commission (AEC), predecessor organization to the U.S. Department of Energy (DOE), acquired the facilities in 1948 and established a standards laboratory for the assay of nuclear and non-nuclear materials used in reactor and weapons programs. The work performed at NBL included the following: nuclear material assay, spectral-chemical analysis of lithium, magnesium, beryllium, zirconium, and other materials used in the nuclear fuel cycle; a small-scale boron recovery pilot plant operation; operation of a thorium extraction pilot plant; development of a continuous production system for uranium tetrafluoride; and the preparation of high-purity plutonium sulfate. In addition, 500 m^3 (18,000 ft^3) of Belgian-Congo pitchblende (a high-grade uranium ore) was transferred to the site in 1960 from the Middlesex Municipal Landfill, mixed with 2,600 m^3 of clean soil, and used as fill on an abandoned railroad spur located on the site. The above activities resulted in radiological contamination of the property.

The NBL operated in this capacity until 1977, at which time the laboratory was deactivated. Remedial actions, conducted in two phases, were initiated in 1978 and completed in 1983. The remediation began with decommissioning the facility and preliminary decontamination of structures and equipment. This phase was followed by removal of structures and sewer lines, and subsequent transport of contaminated materials off-site. Approximately 340 m^3 of contaminated site soils were excavated and placed near the soil containing the Middlesex pitchblende. A foundation and parking lot are the only remaining structures. After completion of these first two phases of remedial action, radiological verification surveys and sampling were performed for the western two-thirds of the site.

Because residual soil contamination remained on the property following the remedial actions completed in 1983, the DOE included the site in its Formerly Utilized Sites Remedial Action Program (FUSRAP) in order to develop appropriate remedial response actions. FUSRAP was created in 1974 to identify and eliminate residual radioactive contamination that exceeds current guidelines from sites utilized during the early years of the nation's atomic energy program. Bechtel National, Inc. (BNI), the FUSRAP project management contractor (PMC), has remediated the remaining contaminated soils from the site. These soils were located on the eastern one-third of the property and included the pitchblende contaminated soil and the soil excavated and left on-site during the Phase 1 and 2 remedial activities. BNI remediated the site by initially excavating contaminated soils. Soils were then processed through a segmented gate system (SGS)—a mechanical unit designed to segregate the soil into two streams; a contaminated soil stream and the soil stream containing residual radionuclide concentrations below the cleanup guidelines. Contaminated soils were subsequently transported off-site for disposal at a licensed facility. The remaining soils were used as backfill in the site excavations following the completion of BNI's post-remedial action (post-RA) surveys.

It is the policy of the DOE-Headquarters' (DOE-HQ) Office of Environmental Restoration to perform independent verification of remedial actions conducted under FUSRAP. The Environmental Survey and Site Assessment Program (ESSAP) of the Oak Ridge Institute for Science and Education (ORISE) was designated as the independent verification contractor (IVC) for the New Brunswick Laboratory Site.

SITE DESCRIPTION

The NBL site is located on Jersey Avenue approximately 3.2 kilometers [km (2 miles)] southwest of downtown New Brunswick, New Jersey (Figure 1). The 2.3 hectare (5.6 acre) site is encircled by a cyclone fence and bounded by commercial property to the north and south, Jersey Avenue to the west, and the Pennsylvania Railroad to the east (Figure 2). The only remaining structures on the property include an asphalt parking lot and one building foundation slab in the southwest sector

of the property. Remediation activities for the remaining contaminated soil encompassed the eastern one-third of the property.

PROJECT ORGANIZATION AND RESPONSIBILITY

DOE-HQ provided overview and coordination of all FUSRAP activities. DOE's Oak Ridge Operations (DOE-ORO) was responsible for implementation of FUSRAP, and the Former Sites Restoration Division (FSRD) of DOE-ORO managed the daily activities.

Under the standard FUSRAP protocol, ORISE or Oak Ridge National Laboratory (ORNL) performed the initial investigation/survey of a potential site under contract to DOE-HQ. If appropriate, DOE-HQ designated the site into FUSRAP based upon the results provided by the initial investigation. BNI was responsible for the planning and the implementation of FUSRAP activities and managing the site characterization and remedial actions. The final phase for a FUSRAP site was independent verification, which was provided by ORISE after the remedial action was completed. This verification process provided independent (third party) data to assist DOE in evaluating the accuracy of the post-remedial action status of the site, as presented by BNI, and in assuring that the documentation accurately and adequately describes the radiological condition of the site. DOE-HQ used the information developed by the remediation and verification activities to certify that a site can be released without radiological restrictions.

OBJECTIVES

The objectives of the verification process were to ensure that the survey, sample analyses, and supporting documentation provided by BNI are accurate and complete and describe the complete radiological condition of the NBL site. The information was used by the DOE to make a decision that all applicable DOE guidelines have been met that will authorize use of the property without restrictions due to residual radioactive materials.

DOCUMENT REVIEW

ESSAP reviewed BNI's field data results, supporting documentation, and Post- Remedial Action Report (PRAR) (BNI 1997). Information was evaluated to assure that areas identified as exceeding site guidelines had undergone decontamination and that residual radioactive material and exposure rates satisfied the established guidelines. The data were reviewed for accuracy, completeness, and compliance with guidelines.

PROCEDURES

A survey team from ESSAP performed independent gamma surface scans, soil sampling, and exposure rate measurements on five occasions from August 18 through November 6, 1996. Survey activities were conducted in accordance with a site-specific survey plan dated June 3, 1996 (ORISE 1996), submitted to and approved by the DOE. The procedures and instrumentation used are described in the ORISE/ESSAP Survey Procedures and Quality Assurance Manuals (ORISE 1995a and b). This report summarizes the procedures and results of survey activities performed at NBL.

REFERENCE SYSTEM

ESSAP referenced measurement and sampling locations to either the 10 m × 10 m grid system established by BNI or to prominent site features.

SURFACE SCANS

Surface scans for gamma activity were performed over 100 percent of remediated soil areas, the previously remediated western region of the property, and the SGS-processed soil piles. Gamma scans of each one meter lift interval were also performed in the excavated areas as the processed soil piles were placed in as backfill. Gamma scans were performed using NaI scintillation detectors. Surface scans for alpha and beta radiation were performed over 50 percent of the remaining asphalt

and concrete surfaces using GM and ZnS detectors. All detectors were coupled to ratemeters or ratemeter-scalers with audible indicators. Locations of elevated direct radiation were identified for further investigation.

SURFACE ACTIVITY MEASUREMENTS

Ten direct measurements for total beta and total alpha surface activity were performed at random locations on the remaining asphalt and concrete surfaces using GM and ZnS detectors coupled to ratemeter-scalers. A smear sample for determining removable activity was obtained from each measurement location. Measurement and sampling locations for total and removable surface activity are illustrated in Figure 3.

EXPOSURE RATE MEASUREMENTS

Background exposure rate measurements were performed at seven locations within a 0.5 to 10 km radius of the NBL site (Figure 4). Site exposure rate measurements were performed at 44 locations (Figures 5 through 7). Exposure rates were measured one meter above the surface using a microrem meter.

SOIL SAMPLING

Background soil samples were collected from each background exposure rate measurement location (Figure 4). Within the eastern remediated portion of the site, soil samples were collected from within 24 of the 87 grid blocks. Sample locations were selected either randomly or based on surface scan results; samples were collected at the center and at four points equidistance between the center and grid block corners within each selected grid block. Additional samples were collected from locations of elevated direct gamma radiation identified by surface scans and from the contiguous area as necessary to determine the average radionuclide concentration level over a 100 m^2 area (Figures 5 and 6). Within the western region of the site, a total of nine soil samples was collected from randomly selected grid blocks (Figure 7). Soil samples were also randomly collected from ten soil

stockpiles—representing the segregated soils that were evaluated by BNI and determined to be below the guidelines.

SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data were returned to the ORISE/ESSAP laboratory in Oak Ridge, Tennessee for analysis and interpretation. Sample analyses were performed in accordance with ESSAP's Laboratory Procedures Manual (ORISE 1995c). Soil samples were analyzed by solid-state gamma spectrometry. The radionuclides of interest were U-238, U-235, and Ra-226; however, spectra were reviewed for other identifiable photopeaks. Soil sample results were reported in units of picocuries per gram (pCi/g). Exposure rates were reported in microroentgens per hour (μR/h). Additional information regarding major instrumentation, sampling equipment, and analytical procedures is provided in Appendices A and B.

FINDINGS AND RESULTS

Document Review

ESSAP reviewed the PMC's post-remedial action survey plan, the PRAR, and at the time of each of the verification surveys the data for each remediated area was also reviewed. ESSAP directly notified the PMC concerning any deficiencies identified in the documentation and of areas exceeding guidelines following verification survey activities.

Surface Scans

Surface scans within the remediated eastern portion of the site identified several locations of elevated direct gamma radiation, as well as numerous discrete particles of pitchblende ore randomly located throughout the remediated eastern portion of the site. Scans of the remaining grid block soils, asphalt, and concrete surfaces of the western portion of the site did not identify any additional areas of elevated direct radiation. ESSAP notified BNI of these findings and BNI performed additional remediation to eliminate these identified locations.

SURFACE ACTIVITY LEVELS

Surface activity levels are summarized in Table 1. Total surface activity levels ranged from 16 to 56 dpm/100 cm^2 for alpha and from -160 to 590 dpm/100 cm^2 for beta. Removable surface activity levels ranged from -2 to 3 dpm/100 cm^2 and from -4 to 5 dpm/100 cm^2 for gross alpha and gross beta, respectively.

EXPOSURE RATES

Background exposure rates are summarized in Table 2. Background exposure rates ranged from 8 to 11 μR/h, with an averaged exposure rate of 9 μR/h. Site exposure rate measurements are summarized in Table 3 and ranged from 7 to 19 μR/h with an average exposure rate of 11 μR/h. All site exposure rates include background.

RADIONUCLIDE CONCENTRATIONS IN SOIL

Background radionuclide concentrations in soil samples are summarized in Table 2, and averaged 0.8 pCi/g for Ra-226, less than 0.2 pCi/g for U-235, 1.1 pCi/g for U-238, and less than 2.4 pCi/g for total uranium. Radionuclide concentrations in site soil samples are summarized in Table 3. The radionuclide concentrations in the 21 selected grid blocks within the excavated areas ranged as follows: Ra-226, less than 0.4 to 8.3 pCi/g; U-235, less than 0.7 to 1.8 pCi/g; U-238, less than 2.1 to 32 pCi/g; and total uranium, less than 12 to 65 pCi/g. The radionuclide concentrations in the soil stock pile samples ranged as follows: Ra-226, 3.1 to 31.9 pCi/g, U-235, 0.2 to 2.0 pCi/g, U-238, 3.9 to 16 pCi/g; and total uranium 8.2 to 34 pCi/g. The radionuclide concentrations in the soil samples collected from three selected grid blocks after the stockpiled soils were placed as backfill ranged as follows: Ra-226, 1.3 to 26.6 pCi/g; U-235, less than 0.3 to 1.2 pCi/g; U-238, 2.1 to 9.5 pCi/g; and total uranium less than 6.4 to 20 pCi/g. The radionuclide concentrations in the nine selected areas in the West region ranged as follows; Ra-226, 1.2 to 1.5 pCi/g; U-235, less than 0.3 to 0.4 pCi/g; U-238, 0.8 to 3.1 pCi/g; and total uranium, less than 5.7 to 6.6 pCi/g.

COMPARISON OF RESULTS WITH GUIDELINES

Surface activity levels for the NBL site were compared to the residual surface contamination guidelines found in DOE Order 5400.5 (DOE 1990). The applicable surface contamination guidelines are those for uranium which are as follows:

Total Activity

5,000 α dpm/100 cm^2 averaged over a 1 m^2 area

15,000 α dpm/100 cm^2 maximum in a 100 cm^2 area

Removable Activity

1,000 α dpm/100 cm

Because natural uranium emits both alpha and beta radiation in approximately equal ratios, and surface conditions—such as the presence of dirt on surfaces—selectively attenuate alpha radiation, the beta surface activity was considered to be more representative for comparison to the guidelines. All surface activity levels satisfy these guidelines.

The basic dose limit for exterior land areas is 100 mrem/yr, which includes external exposure plus the sum of all other pathways. In implementing this limit, the DOE also applies as low as reasonably achievable principles (DOE 1990). Exterior exposure rates were at or near background levels and satisfy the guideline.

Residual radionuclide concentrations in soils were compared to the DOE's generic Ra-226 guideline and site-specific guideline for total uranium (DOE 1990 and DOE 1995). These guidelines are summarized in Appendix C and are as follows:

Radionuclide	Residual Concentration Guideline
Radium-226	5 pCi/g, averaged over the first 15 cm of soil below the surface; 15 pCi/g, averaged over 15 cm thick layer of soil greater than 15 cm below the surface
Total Uranium	100 pCi/g, calculated on a site-specific basis, using the DOE manual developed for this use.

Although the guidelines specify a 15 pCi/g limit for Ra-226 at depths greater than 15 cm below the surface, BNI elected to base compliance only on the surface guideline of 5 pCi/g.

All final verification soil sample results were less than the 100 pCi/g total uranium guideline. Eight soil samples—one each from grid blocks S29, S38, and S40 and six of the ten soil samples from the SGS soil piles—exceeded the residual radionuclide concentration guideline of 5 pCi/g for Ra-226. The residual Ra-226 concentration in these samples were as follows: grid block S29—sample #81, 8.3 pCi/g; grid block S38—sample #14, 7.6 pCi/g; grid block S40—sample #65, 27 pCi/g. However, the guidelines permit averaging the residual soil concentration within the contiguous 100 m^2 area and application of the hot spot criteria. The average Ra-226 concentration, including background, within these grid blocks was as follows: grid block S29, 2.8 pCi/g, S38, 2.8 pCi/g; grid block combination S40 and S48, 5.4 pCi/g (4.5 pCi/g subtracting background).

The six samples from the SGS soil piles—#28, 29, 30, 31, 32, and 34 were 7.4, 6.5, 31.9, 6.8, 6.0, and 5.9 pCi/g Ra-226, respectively. It is ESSAP's opinion that these results are indicative of the operational parameters of the SGS—where small particles of residual contamination were not detected by the system and thus not segregated. This opinion is based on BNI's and ESSAP's SGS analytical results and the numerous other small hot spots that were detected by surface scans during the verification surveys. Surface scans and samples collected from the soil piles—once they were placed back into the excavation and spread out—did not identify any locations of distributed residual contamination. It is possible that the elevated contamination levels within these grid blocks were

similar to other identified hot spots—confined to an area of less than 1 m^2—and would therefore satisfy the guideline based on the averaging criteria.

SUMMARY

ESSAP performed independent verification survey activities during the period of August 18 through November 6, 1996 at the New Brunswick Laboratory site, located in New Brunswick, New Jersey. Verification activities included independent document and data reviews, beta, alpha, and gamma surface scans, soil sampling, and exposure rate measurements. Surface scans identified several locations of elevated direct radiation within the remediated eastern one-third of the site that required additional remediation by BNI, typically the removal of a small volume of soil associated with pitchblende residue. Additionally, the SGS pile sample results indicated that the SGS process was not reliable for segregation of small particles at or near 5 pCi/g of Ra-226.

Surface activity levels for the asphalt and concrete surface areas were below the total and removable residual surface activity guidelines. In addition, radionuclide concentrations satisfy the guidelines for total uranium and for the averaging and hot spot criteria for Ra-226. Site exposure rates were comparable to background levels, and satisfy the guideline. Since soils from the SGS piles were used as backfill at depths below 15 cm, the Ra-226 guideline at that depth is 15 pCi/g. Therefore, the results of the verification survey support BNI's conclusion that the radiological conditions of the New Brunswick Laboratory site satisfy the DOE guidelines for release without radiological restrictions.

FIGURES

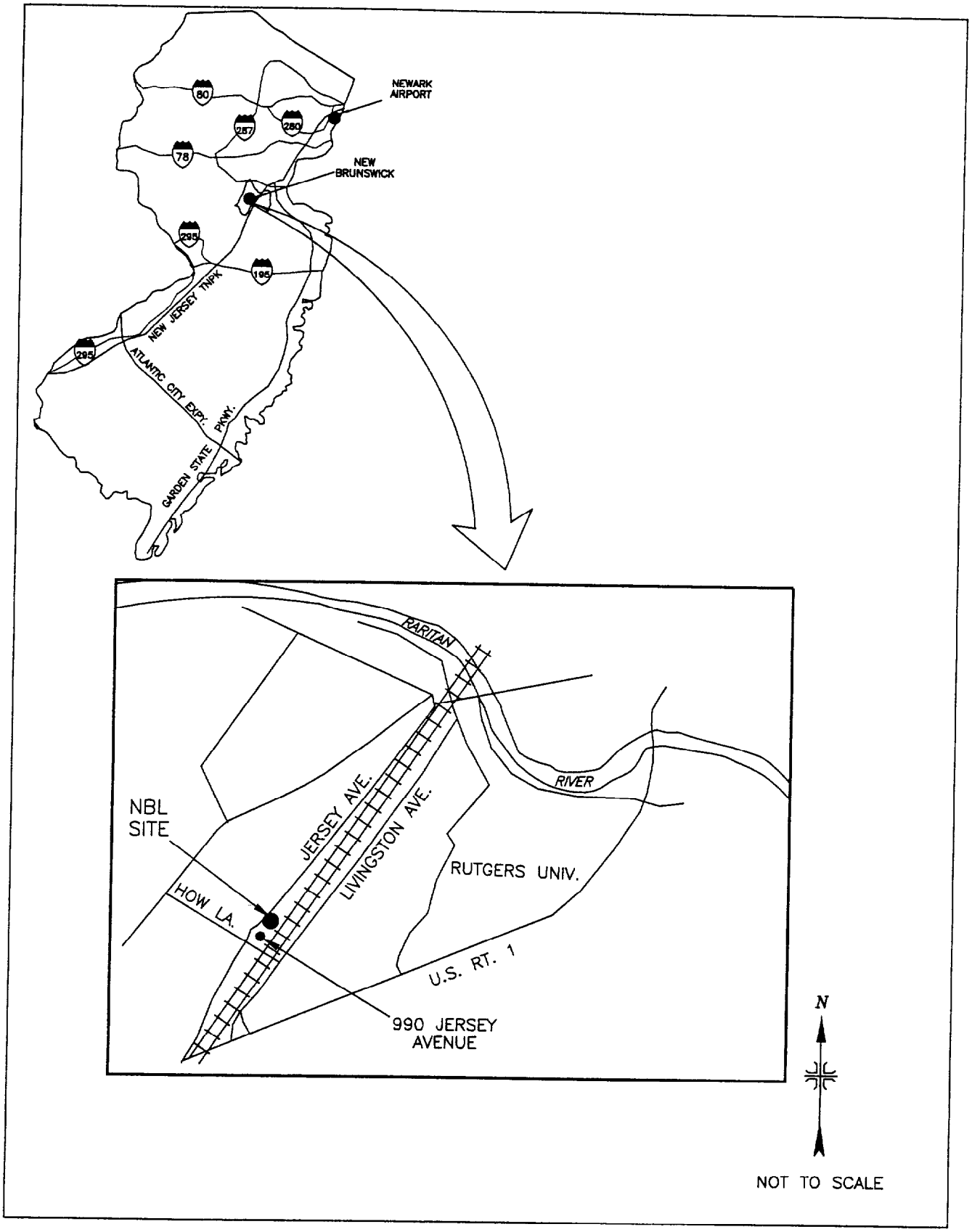

FIGURE 1: Location of the New Brunswick Laboratory Site, New Brunswick, New Jersey

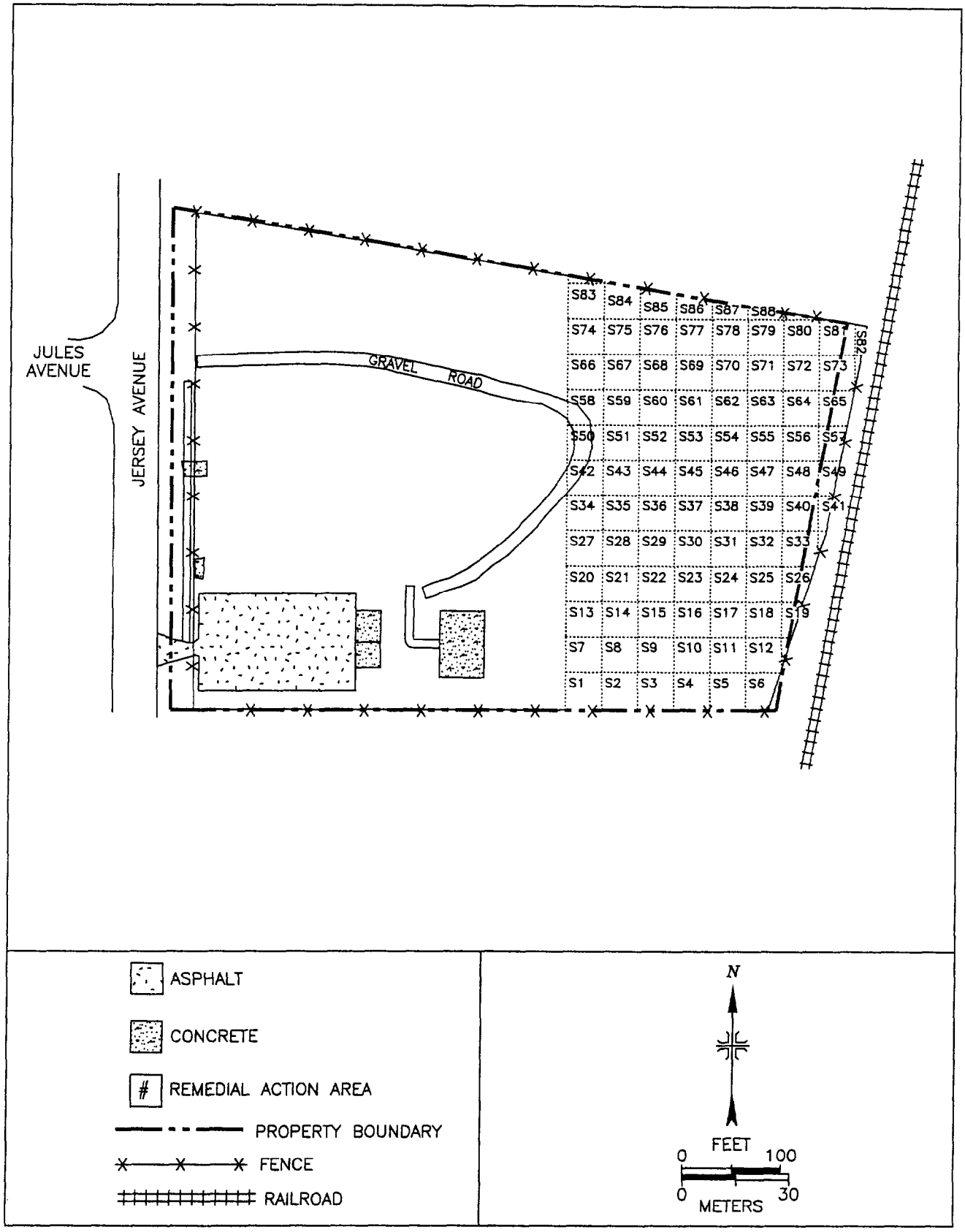

FIGURE 2: New Brunswick Laboratory Site – Site Plan and Remedial Action Grid Blocks

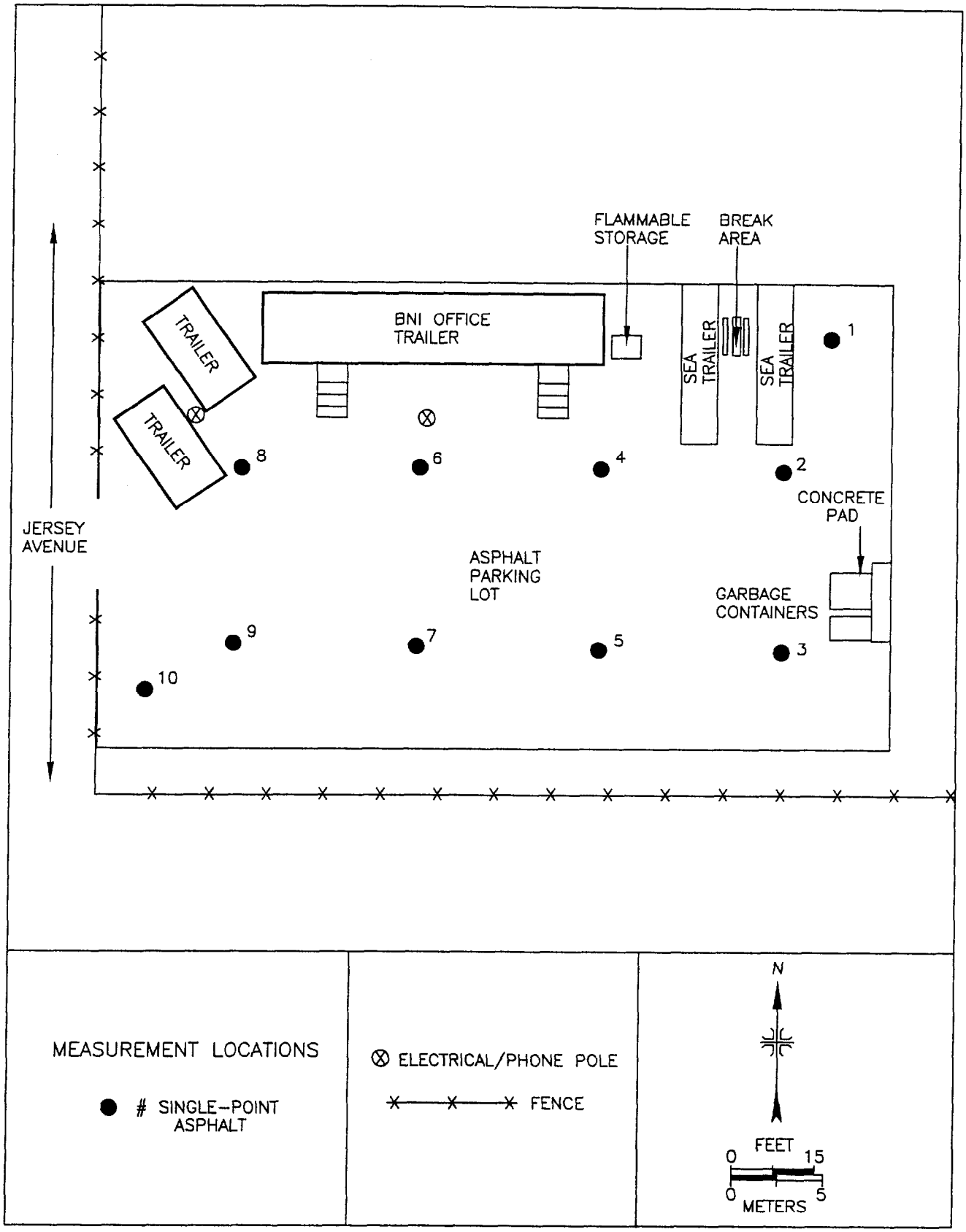

FIGURE 3: New Brunswick Laboratory Site – Parking Lot Measurement and Sampling Locations

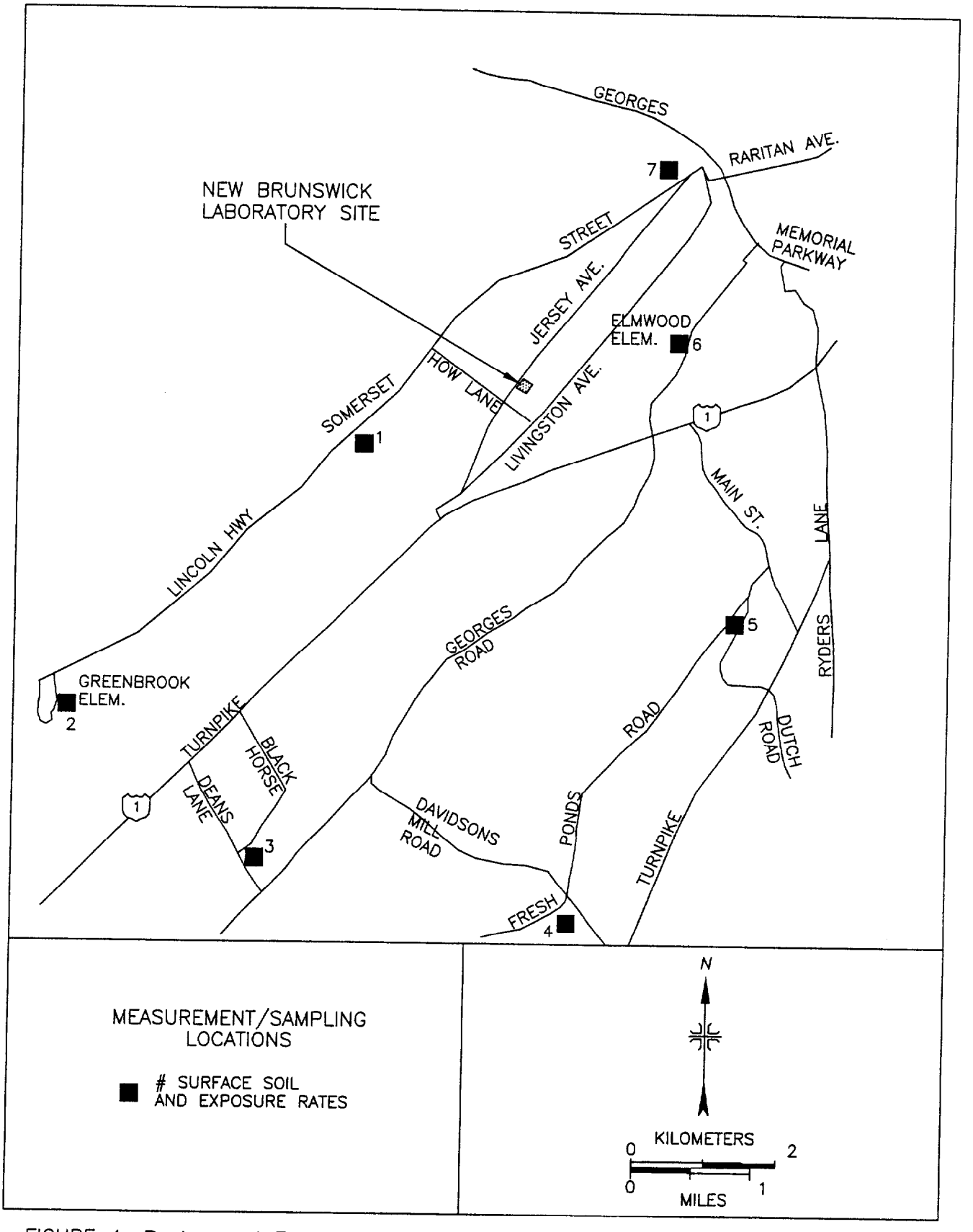

FIGURE 4: Background Exposure Rate Measurements and Soil Sampling Locations – New Brunswick, New Jersey

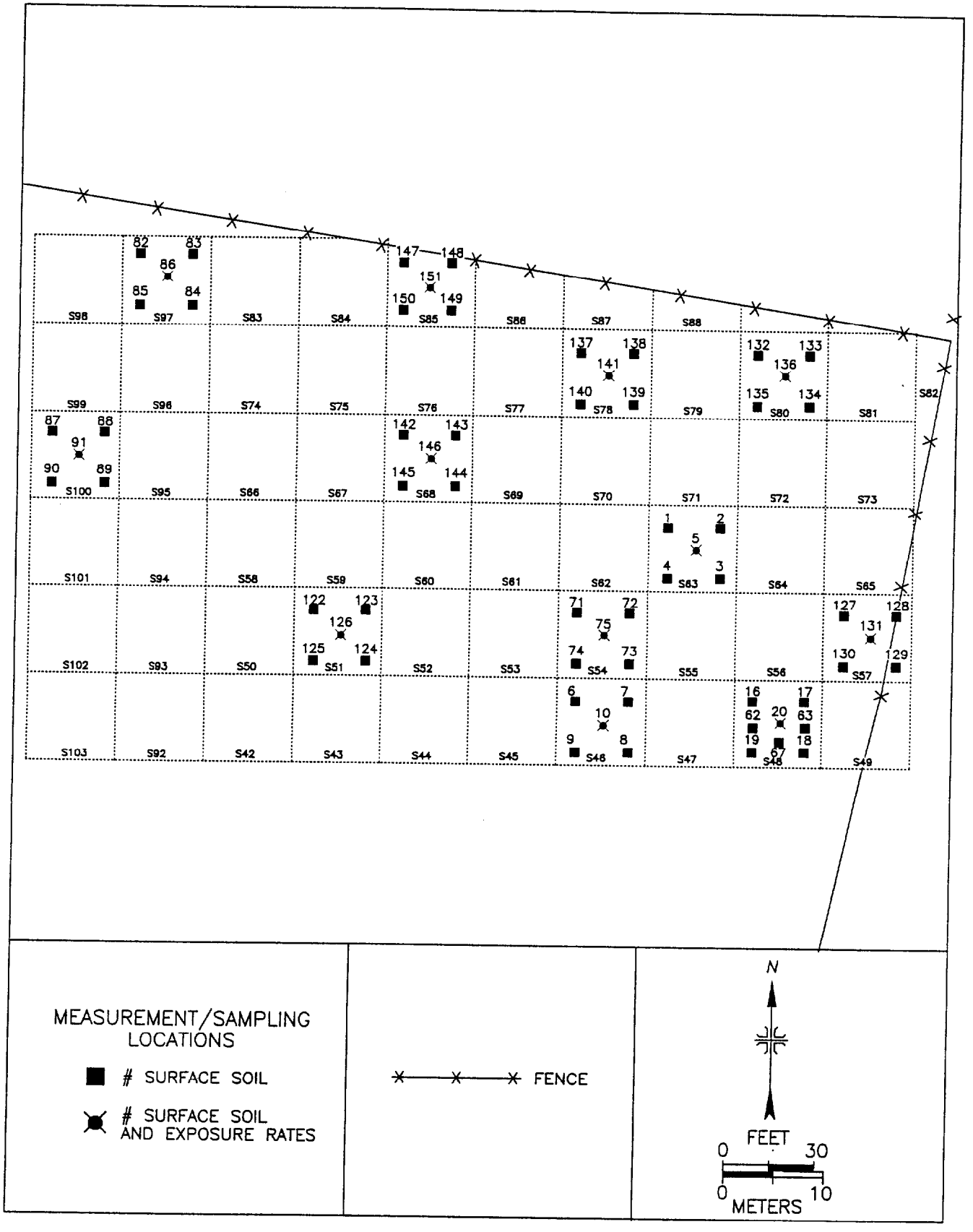

FIGURE 5: New Brunswick Laboratory Site – Northeast Region
Measurement and Sampling Locations

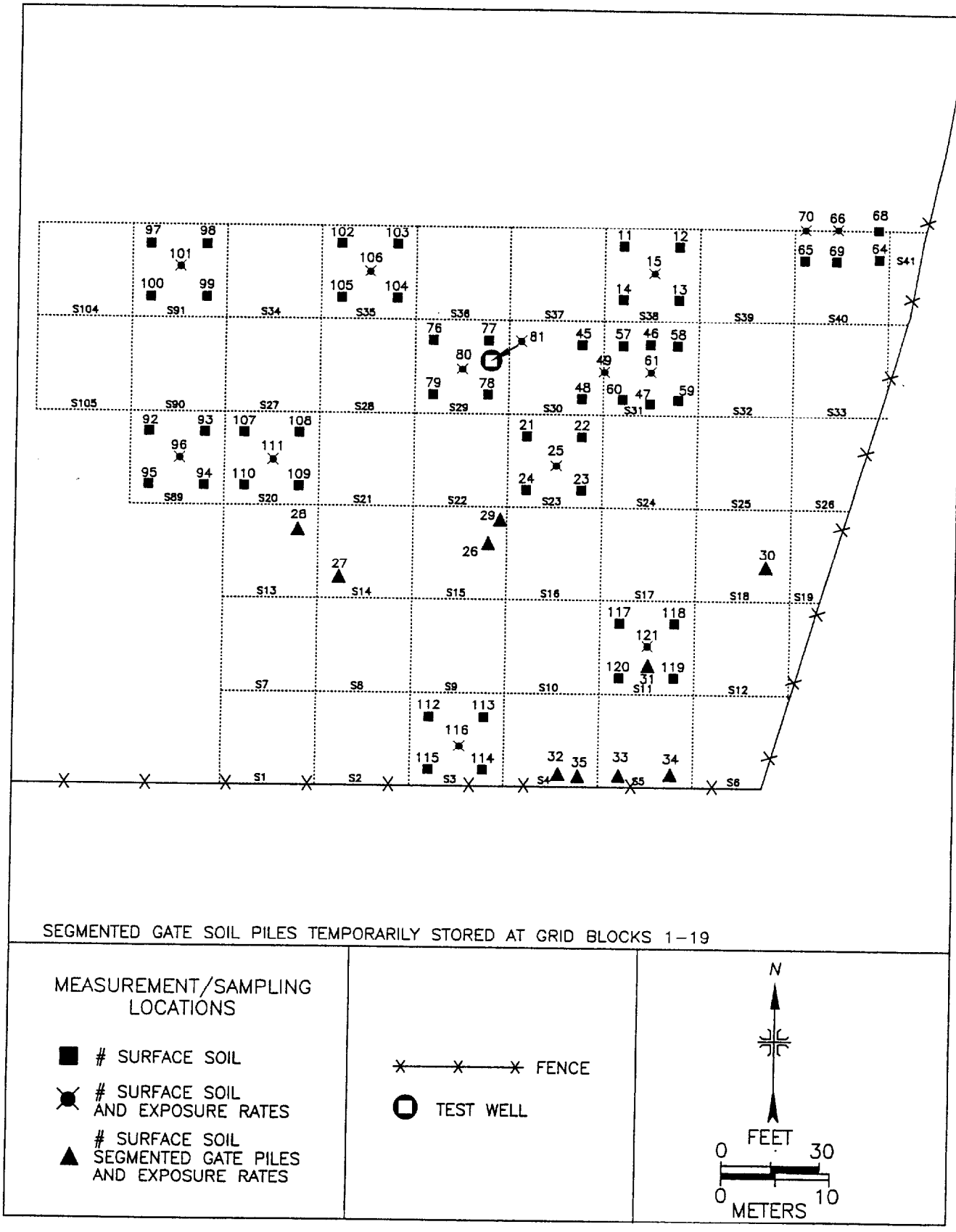

FIGURE 6: New Brunswick Laboratory Site – Southeast Region
Measurement and Sampling Locations

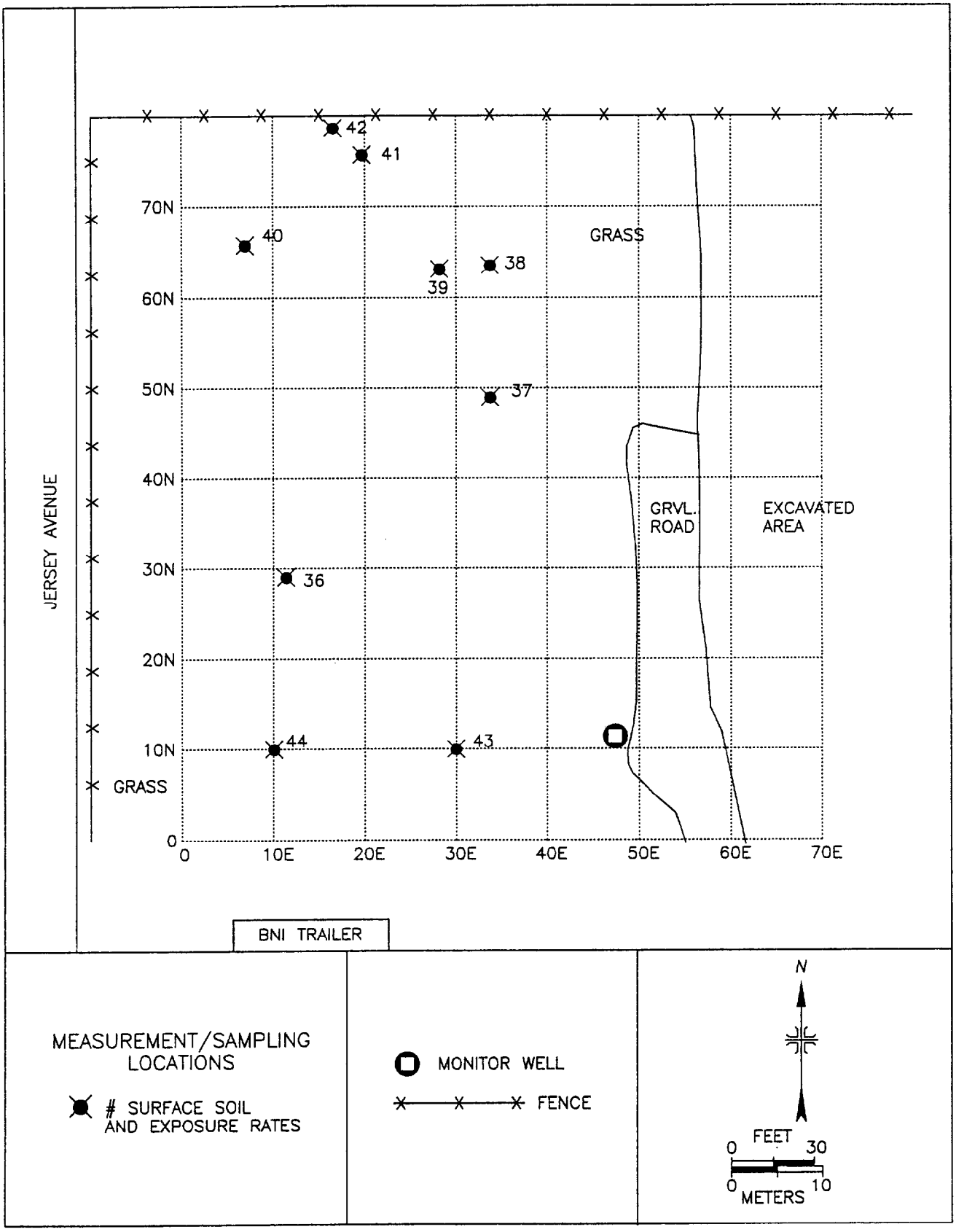

FIGURE 7: New Brunswick Laboratory Site – West Region, Measurement and Sampling Locations

TABLES

TABLE 1

SUMMARY OF SURFACE ACTIVITY LEVELS
NEW BRUNSWICK LABORATORY SITE
NEW BRUNSWICK, NEW JERSEY SITE

Location[a]	Total Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)	
	Single Point Measurements			
	Alpha[b]	Beta[c]	Alpha[d]	Beta[e]
ASPHALT AND CONCRETE PAD				
1	56	270	1	-4
2	56	160	1	1
3	24	450	1	2
4	26	23	1	1
5	56	160	-2	-4
6	32	590	3	2
7	40	180	-2	-1
8	16	90	-2	5
9	24	-160	1	1
10	24	140	1	-3

[a]Refer to Figure 3.
[b]Minimum detectable concentration was 59 dpm/100 cm^2.
[c]Minimum detectable concentration was 770 dpm/100 cm^2.
[d]Minimum detectable concentration was 14 dpm/100 cm^2.
[e]Minimum detectable concentration was 16 dpm/100 cm^2.

TABLE 2

BACKGROUND EXPOSURE RATES AND RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES NEW BRUNSWICK LABORATORY SITE NEW BRUNSWICK, NEW JERSEY

Location[a]	Exposure Rates (μR/h)	Radionuclide Concentrations (pCi/g)			
		Ra-226	U-235	U-238	Total U[b]
1	11	0.9 ± 0.1[c]	<0.3	1.4 ± 0.9	<3.1
2	11	1.1 ± 0.1	<0.2	1.8 ± 0.6	<4.0
3	9	0.8 ± 0.1	<0.1	0.7 ± 0.5	<1.5
4	8	0.3 ± 0.1	<0.2	0.4 ± 0.4	<1.0
5	8	0.7 ± 0.1	<0.1	0.5 ± 0.4	<1.1
6	8	0.7 ± 0.1	<0.2	1.3 ± 0.7	<2.8
7	10	0.9 ± 0.1	<0.2	2.1 ± 0.8	<4.4
Average	9.3	0.8	<0.2	1.1	<2.4

[a]Refer to Figure 4.
[b]Total uranium concentrations were calculated by multiplying the U-238 concentration by two and adding the U-235 concentration.
[c]Uncertainties represent the 95% confidence level, based only on counting statistics.

TABLE 3

EXPOSURE RATES AND RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES NEW BRUNSWICK LABORATORY SITE NEW BRUNSWICK, NEW JERSEY

Location[a]	Exposure Rates at 1 m (μR/h)[b]	Radionuclide Concentrations[c] (pCi/g)			
		Ra-226	U-235	U-238	Total U[d]
GRID S3					
112	---[e]	1.1 ± 0.2[f]	<0.5	3.4 ± 1.8	<7.3
113	---	2.1 ± 0.3	0.3 ± 0.4	4.0 ± 1.9	8.3
114	---	0.9 ± 0.2	<0.3	<1.6	<3.5
115	---	1.0 ± 0.2	<0.5	1.7 ± 1.4	<3.9
116	15	1.2 ± 0.2	<0.4	1.8 ± 1.3	<4.0
GRID S11					
117	---	2.0 ± 0.2	<0.5	5.6 ± 1.8	<12
118	---	2.4 ± 0.3	<0.7	4.2 ± 1.6	<9.1
119	---	1.0 ± 0.2	<0.4	2.9 ± 1.6	<6.2
120	---	2.2 ± 0.2	<0.5	4.4 ± 1.4	<9.3
121	19	1.6 ± 0.2	<0.6	3.3 ± 1.4	<7.2
GRID S20					
107	---	0.8 ± 0.2	<0.4	1.8 ±1.2	<4.0
108	---	0.1 ± 0.2	<0.4	1.8 ± 1.0	<4.0
109	---	<0.4	<0.5	1.3 ± 1.0	<3.1
110	---	0.8 ± 0.2	<0.4	1.6 ± 1.1	<3.6
111	16	0.8 ± 0.2	<0.4	3.0 ± 1.6	<6.4
GRID S23					
21	---	1.3 ± 0.1	<0.2	1.3 ± 0.7	<2.8

TABLE 3 (Continued)

EXPOSURE RATES AND RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
NEW BRUNSWICK LABORATORY SITE
NEW BRUNSWICK, NEW JERSEY

Location[a]	Exposure Rates at 1 m (μR/h)[b]	Radionuclide Concentrations (pCi/g)[c]			
		Ra-226	U-235	U-238	Total U[d]
GRID S23 (Continued)					
22	---	2.0 ± 0.1	<0.2	1.4 ± 0.6	<3.0
23	---	1.2 ± 0.1	<0.2	1.5 ± 0.7	<3.2
24	---	1.1 ± 0.1	<0.2	1.8 ± 0.8	<3.8
25	12	1.3 ± 0.1	<0.2	0.6 ± 0.6	<1.4
GRID S29					
76	---	1.7 ± 0.1	1.0 ± 0.2	16 ± 1.1	33
77	---	1.6 ± 0.1	<0.2	2.4 ± 0.6	<5.0
78	---	1.7 ± 0.1	0.2 ± 0.2	3.4 ± 1.0	7.0
79	---	2.0 ± 0.1	0.3 ± 0.2	6.3 ± 1.0	13
80	11	1.4 ± 0.1	0.2 ± 0.1	4.0 ± 0.8	8.2
81	11	8.3 ± 0.2	0.9 ± 0.3	12 ± 1.3	25
100 m^2 Average		2.8 ± 0.2			
GRID S30 & 31 BACKFILL					
45	---	1.3 ± 0.1	<0.2	3.1 ± 0.7	<6.4
46	---	2.2 ± 0.1	0.4 ± 0.2	3.8 ± 0.8	8.0
47	---	2.3 ± 0.1	0.3 ± 0.2	5.1 ± 0.9	11
48	---	1.9 ± 0.2	0.2 ± 0.2	3.3 ± 0.8	6.8
49	17	2.5 ± 0.1	0.3 ± 0.2	3.9 ± 0.8	8.1
GRID S31 BACKFILL					
57	---	3.0 ± 0.2	0.4 ± 0.2	4.9 ± 1.0	10.2
58	---	2.6 ± 0.1	0.4 ± 0.2	4.5 ± 0.9	9.4

TABLE 3 (Continued)

EXPOSURE RATES AND RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES NEW BRUNSWICK LABORATORY SITE NEW BRUNSWICK, NEW JERSEY

Location[a]	Exposure Rates at 1 m (μR/h)[b]	Radionuclide Concentrations (pCi/g)[c]			
		Ra-226	U-235	U-238	Total U[d]
GRID S31 BACKFILL(Continued)					
59	---	1.3 ± 0.1	<0.3	2.2 ± 0.6	<4.7
60	---	1.3 ± 0.1	0.2 ± 0.2	2.1 ± 0.7	4.4
61	16	2.6 ± 0.1	0.3 ± 0.2	5.1 ± 1.0	11
GRID S35					
102	---	0.9 ± 0.2	<0.4	1.9 ± 1.4	<4.2
103	---	<0.4	<0.5	<1.9	<4.3
104	---	0.7 ± 0.1	<0.4	1.4 ± 1.0	<3.2
105	---	<0.2	<0.2	1.1 ± 0.9	<2.4
106	19	0.8 ± 0.2	<0.6	4.1 ± 1.0	<8.8
GRID S38					
11	---	1.2 ± 0.1	<0.2	1.8 ± 0.8	<3.8
12	---	1.0 ± 0.1	<0.2	1.1 ± 0.5	<2.4
13	---	1.8 ± 0.1	0.2 ± 0.2	6.0 ± 1.0	12
14	---	7.6 ± 0.2	1.2 ± 0.3	20 ± 1.5	41
15	17	2.6 ± 0.1	1.8 ± 0.2	32 ± 1.5	65
100 m^2 Average		2.8 ± 0.2			
GRID S40 & 48 BACKFILL					
62	---	3.2 ± 0.2	0.2 ± 0.2	5.3 ± 1.1	11
63	---	3.5 ± 0.2	0.6 ± 0.2	5.0 ± 1.1	11
64	---	2.3 ± 0.1	0.3 ± 0.2	3.2 ± 0.8	6.7
65	---	26.6 ± 0.4	1.2 ± 0.4	9.5 ± 1.6	20

TABLE 3 (Continued)

EXPOSURE RATES AND RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES NEW BRUNSWICK LABORATORY SITE NEW BRUNSWICK, NEW JERSEY

Location[a]	Exposure Rates at 1 m (μR/h)[b]	Radionuclide Concentrations (pCi/g)[c]			
		Ra-226	U-235	U-238	Total U[d]
GRID S40 & 48 BACKFILL(Continued)					
66	17	2.6 ± 0.1	0.4 ± 0.2	4.5 ± 1.0	9.4
67	---	2.9 ± 0.2	0.4 ± 0.2	3.4 ± 0.9	7.2
68	---	2.0 ± 0.1	0.3 ± 0.2	3.1 ± 0.8	6.5
69	---	2.6 ± 0.2	0.3 ± 0.2	3.1 ± 0.9	6.5
70	14	2.8 ± 0.1	0.2 ± 0.2	4.0 ± 0.9	8.2
100 m^2 Average		5.4[g] ± 0.6			
GRID S46					
6	---	1.4 ± 0.2	<0.2	2.1 ± 0.9	<4.4
7	---	1.0 ± 0.1	<0.2	1.5 ± 0.8	<3.2
8	---	1.4 ± 0.1	<0.2	2.8 ± 1.1	<5.8
9	---	0.9 ± 0.1	<0.2	1.1 ± 0.6	<2.5
10	12	1.0 ± 0.1	<0.2	0.9 ± 0.5	<2.0
GRID S48					
16	---	1.5 ± 0.1	<0.2	1.1 ± 0.6	<2.4
17	---	1.5 ± 0.1	0.1 ± 0.2	1.8 ± 0.7	3.7
18	---	0.3 ± 0.1	<0.1	0.7 ± 0.4	<1.5
19	---	0.6 ± 0.1	<0.1	0.1 ± 0.5	<2.1
20	7	0.2 ± 0.1	<0.1	0.6 ± 0.4	<1.3
GRID S51					
122	---	1.0 ± 0.2	<0.3	1.4 ± 1.1	<3.1
123	---	0.8 ± 0.2	<0.4	<1.8	<4.0

TABLE 3 (Continued)

EXPOSURE RATES AND RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES NEW BRUNSWICK LABORATORY SITE NEW BRUNSWICK, NEW JERSEY

Location[a]	Exposure Rates at 1 m (μR/h)[b]	Radionuclide Concentrations (pCi/g)[c]			
		Ra-226	U-235	U-238	Total U[d]
GRID S51 (Continued)					
124	---	1.1 ± 0.2	<0.4	1.1 ± 1.3	<2.6
125	---	0.4 ± 0.1	<0.2	0.9 ± 1.0	<2.0
126	16	0.8 ± 0.1	<0.3	1.9 ± 1.0	<4.1
GRID S54					
71	---	1.2 ± 0.1	<0.2	1.4 ± 0.9	<3.0
72	---	0.9 ± 0.1	<0.2	0.7 ± 0.6	<1.6
73	---	0.9 ± 0.1	<0.2	1.1 ± 0.7	<2.4
74	---	2.3 ± 0.1	<0.2	2.9 ± 0.9	<6.0
75	12	1.0 ± 0.1	<0.2	1.7 ± 0.9	<3.6
GRID S57					
127	---	0.9 ± 0.2	<0.4	2.6 ± 1.6	<5.6
128	---	1.2 ± 0.2	<0.4	1.4 ± 1.2	<3.2
129	---	0.9 ± 0.2	<0.3	1.2 ± 1.1	<2.7
130	---	0.9 ± 0.2	<0.4	<2.0	<4.4
131	12	0.9 ± 0.2	<0.6	2.5 ± 1.5	<5.6
GRID S63					
1	---	1.2 ± 0.2	<0.2	1.5 ± 0.7	<3.2
2	---	1.2 ± 0.1	<0.2	1.6 ± 0.7	<3.4
3	---	1.0 ± 0.1	<0.2	1.3 ± 0.8	<2.8
4	---	1.1 ± 0.2	<0.2	0.7 ± 0.8	<1.6
5	17	1.1 ± 0.1	<0.2	0.7 ± 0.6	<1.6

TABLE 3 (Continued)

EXPOSURE RATES AND RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES NEW BRUNSWICK LABORATORY SITE NEW BRUNSWICK, NEW JERSEY

Location[a]	Exposure Rates at 1 m (μR/h)[b]	Radionuclide Concentrations (pCi/g)[c]			
		Ra-226	U-235	U-238	Total U[d]
GRID S68					
142	---	1.9 ± 0.2	<0.6	3.0 ± 1.6	<6.6
143	---	0.7 ± 0.2	<0.5	1.4 ± 1.3	<3.3
144	---	0.9 ± 0.1	<0.4	<1.5	<3.4
145	---	0.8 ± 0.2	<0.4	<1.7	<3.8
146	8	0.9 ± 0.2	<0.5	0.8 ± 1.1	<2.1
GRID S78					
137	---	1.4 ± 0.2	<0.5	1.7 ± 1.7	<3.9
138	---	0.8 ± 0.2	<0.4	<1.4	<3.2
139	---	1.1 ± 0.2	<0.5	<2.1	<4.7
140	---	0.9 ± 0.2	<0.4	1.6 ± 1.4	<3.6
141	9	0.8 ± 0.1	<0.4	1.4 ± 0.6	<3.2
GRID S80					
132	---	0.7 ± 0.2	<0.3	1.5 ± 1.0	<3.3
133	---	0.8 ± 0.2	<0.4	1.3 ± 1.5	<3.0
134	---	0.7 ± 0.1	<0.3	0.7 ± 0.7	<1.7
135	---	0.5 ± 0.1	<0.3	0.9 ± 1.2	<2.1
136	9	0.8 ± 0.2	<0.5	0.8 ± 1.2	<2.1
GRID S85					
147	---	0.8 ± 0.2	<0.4	<1.5	<3.4
148	---	0.7 ± 0.2	<0.3	1.8 ± 1.2	<3.9
149	---	1.8 ± 0.3	<0.6	2.9 ± 1.3	<6.4

TABLE 3 (Continued)

EXPOSURE RATES AND RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
NEW BRUNSWICK LABORATORY SITE
NEW BRUNSWICK, NEW JERSEY

Location[a]	Exposure Rates at 1 m (μR/h)[b]	Radionuclide Concentrations (pCi/g)[c]			
		Ra-226	U-235	U-238	Total U[d]
GRID S85 (Continued)					
150	---	1.1 ± 0.2	<0.4	0.5 ± 1.1	<1.4
151	10	1.8 ± 0.2	<0.4	3.0 ± 1.2	<6.4
GRID S89					
92	---	1.0 ± 0.2	<0.4	1.2 ± 1.3	<2.8
93	---	0.9 ± 0.2	<0.4	1.9 ± 1.2	<4.2
94	---	0.9 ± 0.2	<0.5	<2.1	<4.7
95	---	0.8 ± 0.2	<0.4	1.0 ± 1.3	<2.4
96	17	0.9 ± 0.2	<0.4	1.4 ± 1.2	<3.2
GRID S91					
97	---	0.5 ± 0.1	<0.3	<1.4	<3.1
98	---	0.3 ± 0.1	<0.2	0.1 ± 0.8	<0.4
99	---	0.5 ± 0.1	<0.3	0.5 ± 0.9	<1.3
100	---	0.4 ± 0.1	0.2 ± 0.2	<1.4	<3.0
101	14	<0.2	<0.2	<1.0	<2.2
GRID S97					
82	---	<0.4	<0.5	1.2 ± 1.2	<2.9
83	---	0.9 ± 0.2	<0.4	2.1 ± 1.3	<4.6
84	---	1.0 ± 0.2	<0.4	1.5 ± 1.5	<3.4
85	---	0.9 ± 0.2	<0.5	<2.0	<4.5
86	19	1.0 ± 0.2	<0.4	1.3 ± 1.2	<3.0

TABLE 3 (Continued)

EXPOSURE RATES AND RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES NEW BRUNSWICK LABORATORY SITE NEW BRUNSWICK, NEW JERSEY

Location[a]	Exposure Rates at 1 m (μR/h)[b]	Radionuclide Concentrations (pCi/g)[c]			
		Ra-226	U-235	U-238	Total U[d]
GRID S100					
87	---	1.0 ± 0.2	<0.4	0.6 ± 1.5	<1.6
88	---	0.9 ± 0.3	<0.6	1.8 ± 1.3	<4.2
89	---	0.9 ± 0.2	<0.4	<1.4	<3.2
90	---	0.4 ± 0.1	<0.2	1.3 ± 0.6	<2.8
91	18	0.9 ± 0.2	<0.6	<2.1	<4.8
SEGMENTED GATE SOIL PILES					
26	13	4.4 ± 0.2	0.3 ± 0.2	6.3 ± 1.0	13
27	13	3.8 ± 0.2	0.5 ± 0.3	6.0 ± 0.9	13
28	14	7.4 ± 0.2	0.7 ± 0.3	10.0 ± 1.4	12
29	14	6.5 ± 0.2	0.3 ± 0.2	6.1 ± 1.1	13
30	13	31.9 ± 0.4	2.0 ± 0.5	16.0 ± 1.9	34
31	15	6.8 ± 0.2	0.6 ± 0.2	8.6 ± 1.2	18
32	15	6.0 ± 0.2	0.4 ± 0.2	5.7 ± 0.9	12
33	13	4.3 ± 0.2	0.3 ± 0.2	4.0 ± 1.0	8.3
34	14	5.9 ± 0.2	0.2 ± 0.2	6.3 ± 0.9	13
35	13	3.1 ± 0.1	0.4 ± 0.2	3.9 ± 0.9	8.2
Soil Pile Average		8.0 ± 0.1			
WEST REGION					
36	9	1.2 ± 0.1	<0.3	2.6 ± 1.2	<5.5

TABLE 3 (Continued)

EXPOSURE RATES AND RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES NEW BRUNSWICK LABORATORY SITE NEW BRUNSWICK, NEW JERSEY

Location[a]	Exposure Rates at 1 m (μR/h)[b]	Radionuclide Concentrations (pCi/g)[c]			
		Ra-226	U-235	U-238	Total U[d]
WEST REGION (Continued)					
37	10	1.4 ± 0.1	<0.3	2.7 ± 1.1	<5.7
38	13	1.2 ± 0.1	<0.3	1.2 ± 0.9	<2.7
39	12	1.4 ± 0.1	0.1 ± 0.2	1.6 ± 0.9	3.3
40	11	1.2 ± 0.1	<0.2	1.0 ± 0.8	<2.2
41	12	1.5 ± 0.1	0.3 ± 0.2	1.7 ± 1.1	3.7
42	14	1.2 ± 0.1	0.4 ± 0.2	3.1 ± 1.2	6.6
43	12	1.3 ± 0.1	<0.2	0.8 ± 0.7	<1.8
44	10	1.2 ± 0.1	<0.3	1.6 ± 1.1	<3.5

[a]Refer to Figures 5 through 7.
[b]Exposure rates include background.
[c]Radionuclide concentrations include background.
[d]Total uranium concentrations were calculated by multiplying the U-238 concentration by two and adding the U-235 concentration.
[e]---exposure rates not performed.
[f]Uncertainties represent the 95% confidence level, based only on counting statistics.
[g]The 100 m^2 average of 5.4 pCi/g includes background. The 100 m^2 average minus background was 4.5 pCi/g.

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APPENDIX A

MAJOR INSTRUMENTATION AND EQUIPMENT

APPENDIX A

MAJOR INSTRUMENTATION AND EQUIPMENT

The display of a specific product is not to be construed as an endorsement of the product or its manufacturer by the authors or their employers.

DIRECT RADIATION MEASUREMENT

Instruments

Eberline Pulse Ratemeter
Model PRM-6
(Eberline, Santa Fe, NM)

Ludlum Ratemeter-Scaler
Model 2221
(Ludlum Measurements, Inc.,
Sweetwater, TX)

Detectors

Bicron Micro-Rem Meter
(Bicron Corporation, Newburg, OH)

Eberline GM Detector
Model HP-260
Physical Detector Area, 20 cm^2
(Eberline, Santa Fe, NM)

Eberline ZnS Scintillation Detector
Model AC-3-7
Physical Detector Area, 74 cm^2
(Eberline, Santa Fe, NM)

Victoreen NaI Scintillation Detector
Model 489-55
3.2 cm x 3.8 cm Crystal
(Victoreen, Cleveland, OH)

LABORATORY ANALYTICAL INSTRUMENTATION

High Purity Extended Range Intrinsic Detectors
Model No: ERVDS30-25195
(Tennelec, Oak Ridge, TN)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, TN) and
Multichannel Analyzer
3100 Vax Workstation
(Canberra, Meriden, CT)

High Purity Extended Range Intrinsic Detector
Model No. GMX-45200-5
(ORTEC)
used in conjunction with:
Lead Shield Model SPG-16-K8
(Nuclear Data)
Multichannel Analyzer
3100 Vax Workstation
(Canberra, Meriden, CT)

High-Purity Germanium Detector
Model GMX-23195-S, 23% Eff.
(EG&G ORTEC, Oak Ridge, TN)
Used in conjunction with:
Lead Shield Model G-16
(Gamma Products, Palos Hills, IL) and
Multichannel Analyzer
3100 Vax Workstation
(Canberra, Meriden, CT)

Low Background Gas Proportional Counter
Model LB-5100-W
(Oxford, Oak Ridge, TN)

APPENDIX B

SURVEY AND ANALYTICAL PROCEDURES

APPENDIX B

SURVEY AND ANALYTICAL PROCEDURES

SURVEY PROCEDURES

Surface Scans

Surface scans were performed by passing the detectors slowly over the surface; the distance between the detector and the surface was maintained at a minimum - nominally about 1 cm. Asphalt or concrete surfaces were scanned using small area (20 and 74 cm^2) hand-held detectors. Identification of elevated levels were based on increases in the audible signal from the recording and/or indicating instrument. Combinations of detectors and instruments used for the scans were:

Alpha	-	ZnS scintillation detector with ratemeter-scaler
Beta-Gamma	-	GM detector with ratemeter-scaler
Gamma	-	NaI scintillation detector with ratemeter

Surface Activity Measurements

Measurements of total alpha and total beta activity levels were performed on randomly selected areas of the remaining asphalt and concrete areas using GM and ZnS detectors with portable ratemeter-scalers.

Count rates (cpm), which were integrated over 1 minute in a static position, were converted to activity levels (dpm/100 cm^2) by dividing the net rate by the 4 π efficiency and correcting for the active area of the detector. The alpha activity background count rate for the ZnS detector was 0 cpm, while the average beta activity background count rate for the GM detector was 50 cpm. The alpha efficiency factor was 0.17 for the ZnS scintillation detector, calibrated to Tl-204 The beta efficiency factor was 0.22 for the GM detector, calibrated to Tc-99. The alpha minimum detectable concentration (MDC) was 59 dpm/100 cm^2, while the beta MDC was 774 dpm/100 cm^2. The effective window areas for the ZnS scintillation and GM detectors were 74 and 20 cm^2, respectively.

Removable Activity Measurements

Removable gross alpha and gross beta activity levels were determined using numbered filter paper disks, 47 mm in diameter. Moderate pressure was applied to the smear and approximately 100 cm^2 of the surface was wiped. Smears were placed in labeled envelopes with the location and other pertinent information recorded.

Exposure Rate Measurements

Measurements of dose equivalent rates (µrem/h) were performed at 1 m above the surface using a Bicron microrem meter. Although the instrument displays data in µrem/h, the µrem/h to µR/h conversion is essentially unity.

Soil Sampling

Approximately 1 kg of soil was collected at each sample location. Collected samples were placed in a plastic bag, sealed, and labeled in accordance with ESSAP survey procedures. Surface soil samples were collected at a depth of 0 to 15 cm.

ANALYTICAL PROCEDURES

Gamma Spectroscopy

Samples of soil were dried, mixed, crushed, and/or homogenized as necessary, and a portion sealed in a 0.5-liter Marinelli beaker or other appropriate container. The quantity placed in the beaker was chosen to reproduce the calibrated counting geometry. Net material weights were determined and the samples counted using intrinsic germanium detectors coupled to a pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. All photopeaks associated with the radionuclides of concern were reviewed for consistency of activity.

Energy peaks used for determining the activities of radionuclides of concern were:

Ra-226	0.352 MeV from Pb-214*
U-235	0.143 MeV
U-238	0.063 MeV from Th-234*

*Secular equilibrium assumed.

Spectra were also reviewed for other identifiable photopeaks.

UNCERTAINTIES AND DETECTION LIMITS

The uncertainties associated with the analytical data presented in the tables of this report represent the 95% confidence level for that data. These uncertainties were calculated based on both the gross sample count levels and the associated background count levels. Additional uncertainties, associated with sampling and measurement procedures, have not been propagated into the data presented in this report.

Detection limits, referred to as minimum detectable concentration (MDC), were based on 2.71 plus 4.65 times the standard deviation of the background count [$2.71 + (4.65\sqrt{BKG})$]. Because of variations in background levels, measurement efficiencies, and contributions from other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument.

CALIBRATION AND QUALITY ASSURANCE

Calibration of all field and laboratory instrumentation was based on standards/sources, traceable to NIST, when such standards/sources were available. In cases where they were not available, standards of an industry-recognized organization were used.

Analytical and field survey activities were conducted in accordance with procedures from the following documents of the Environmental Survey and Site Assessment Program:

- Survey Procedures Manual, Revision 9 (April 1995)
- Laboratory Procedures Manual, Revision 9 (January 1995)
- Quality Assurance Manual, Revision 7 (January 1995)

The procedures contained in these manuals were developed to meet the requirements of DOE Order 5700.6C and ASME NQA-1 for Quality Assurance and contain measures to assess processes during their performance.

Quality control procedures include:

- Daily instrument background and check-source measurements to confirm that equipment operation is within acceptable statistical fluctuations.
- Participation in EPA and EML laboratory Quality Assurance Programs.
- Training and certification of all individuals performing procedures.
- Periodic internal and external audits.

APPENDIX C

RESIDUAL RADIOACTIVE MATERIAL GUIDELINES SUMMARIZED FROM DOE ORDER 5400.5

APPENDIX C

RESIDUAL RADIOACTIVE MATERIAL GUIDELINES SUMMARIZED FROM DOE ORDER 5400.5 (DOE 1990)

BASIC DOSE LIMITS

The basic dose limit for the annual radiation dose (excluding radon) received by an individual member of the general public is 100 mrem/yr. In implementing this limit, DOE applies as low as reasonably achievable principles to set site-specific guidelines.

EXTERNAL GAMMA RADIATION

The average level of gamma radiation inside a building or habitable structure on a site that has no radiological restriction on its use shall not exceed the background level by more than 20 μR/h and will comply with the basic dose limits when an appropriate-use scenario is considered.

SURFACE CONTAMINATION GUIDELINES

Allowable Total Residual Surface Contamination
(dpm/100 cm^2)[a]

Radionuclides[b]	Average[c,d]	Maximum[d,e]	Removable[d,f]
Transuranics, Ra-226, Ra-228, Th-230 Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
Th-Natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000α	15,000α	1,000α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000β-γ	15,000β-γ	1,000β-γ

[a] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[b] Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

[c] Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

[d] The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at a distance of 1 cm.

[e] The maximum contamination level applies to an area of not more than 100 cm^2.

[f] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping an area of that size with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. The numbers in this column are maximum amounts.

SOIL GUIDELINES

Radionuclides	Soil Concentration (pCi/g) Above Background[a,b,c]
Radium-226	5 pCi/g, averaged over the first 15 cm of soil below the surface 15 pCi/g, averaged over 15 cm thick layers of soil greater than 15 cm below the surface
Total Uranium	100 pCi/g, calculated on a site-specific basis, using the DOE manual developed for this use.

[a] These guidelines take into account ingrowth of radium-226 from thorium-230 or thorium-232 and radium-228 and assume secular equilibrium. If either Th-230 and Ra-226 or Th-232 and Ra-228 are both present, not in secular equilibrium, the guidelines apply to the higher concentration. If other mixtures of radionuclides occur, the concentrations of individual radionuclides shall be reduced so that (1) the dose for the mixtures will not exceed the basic dose limit, or (2) the sum of ratios of the soil concentration of each radionuclide to the allowable limit for that radionuclide will not exceed 1 ("unity").

[b] These guidelines represent allowable residual concentrations above background averaged across any 15-cm-thick layer to any depth and over any contiguous 100 m^2 surface area.

[c] If the average concentration in any surface or below-surface area, less than or equal to 25 m^2, exceeds the authorized limit of guideline by a factor of $(100/A)^{1/2}$, where A is the area or the elevated region in square meters, limits for "hot spots" shall also be applicable. Procedures for calculating these hot spot limits, which depend on the extent of the elevated local concentrations, are given in the DOE Manual for Implementing Residual Radioactive Materials Guidelines and the Draft DOE Manual for Implementing Residual Radioactive Material Guidelines using RESRAD, Version 5.0 (ANL 1989/1993). In addition, every reasonable effort shall be made to remove any source of radionuclide that exceeds 30 times the appropriate limit for soil, irrespective of the average concentration in the soil.

REFERENCES

U.S. Department of Energy (DOE), DOE Order 5400.5, Radiation Protection of the Public and the Environment. Washington, D.C.; February 1990.

Argonne National Laboratory (ANL), Manual for Implementing Residual Radioactive Material Guidelines, DOE/CH/8901. Chicago, IL; June 1989. See also, Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0, working draft for comment, ANL/EAD/LD-2. Chicago IL; September 1993.